(12) UK Patent Application (19) GB (11) 2 194 112 (13) A

(43) Application published 24 Feb 1988

(21) Application No 8715497

(22) Date of filing 1 Jul 1987

(30) Priority data
(31) 8617661 (32) 18 Jul 1986 (33) GB

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(51) INT CL⁴
C25B 7/00 G01S 17/88 // 17/58

(52) Domestic classification (Edition J):
H4D 72X 755 772 782 783 788 L LVD
U1S 1265 1285 1303 1457 1606 2154 H4D

(56) Documents cited
None

(58) Field of search
H4D
G1N
Selected US specifications from IPC sub-class C25B

(54) Laser doppler velocimetry

(57) A microelectrophoresis cell incorporates a sample analysis zone 10 forming part of a sample introduction and exhaust flow path 1. Side walls of the cell 10 are defined by a pair of electrodes 2 formed as polished films of indium tin oxide (which is optically transparent) on the walls of prisms 3. Laser beams 6, 7 are reflected by angled surfaces 8, 9 of the prisms to pass through the transparent electrodes 2 and cross within the zone 10. Light scattering effects created by particles are measured by a photomultiplier 11 aligned on the axis of the flow path 1. Because the electrodes 2 are transparent large crossing angles for the beams 6 and 7 can be achieved within the sample.

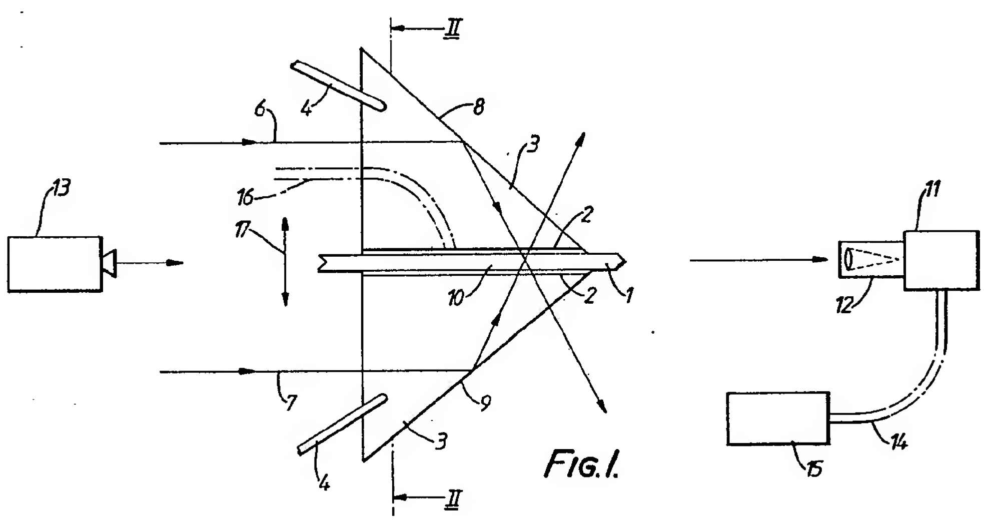

FIG. 1.

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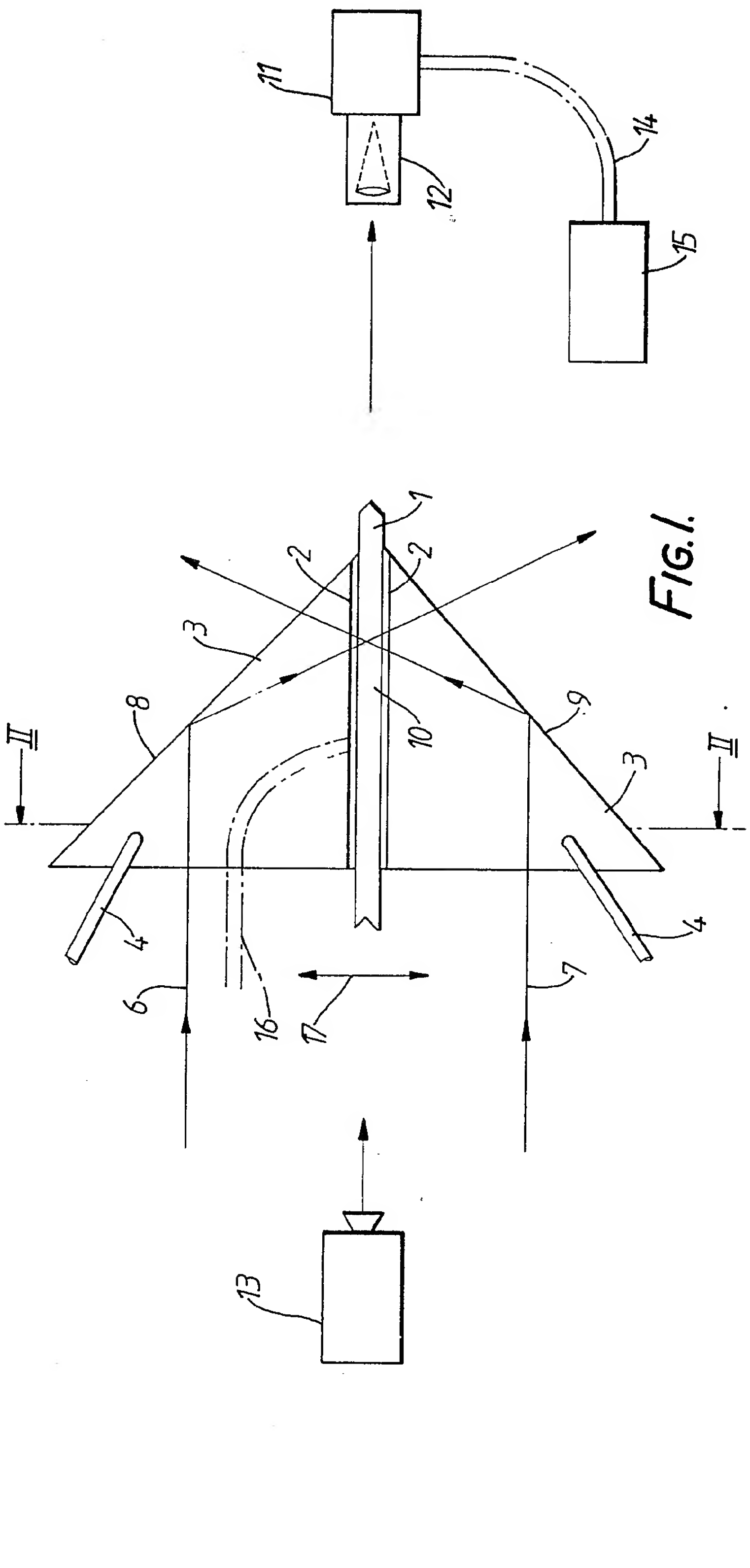

FIG. 1.

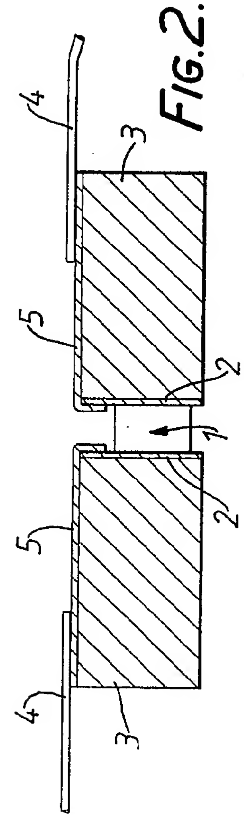

FIG. 2.

SPECIFICATION

Improvements relating to laser doppler velocimetry

Many substances or entities in a dispersed state, including living cells, emulsions, solid minerals or other ground particles carry a net surface charge due to the ionisation of the chemical groups which form the surface. This charge can be studied by the technique of electrophoresis in which the particles or charged entities are suspended in a suitable fluid and an electric field is applied between suitable electrodes. The resultant motion is then measured by some technique, and the sign and magnitude of the potential across the surface of shear can be deduced. This potential is of both theoretical and practical interest in studying and understanding the way the charged entities will behave.

A widely used modern method for studying the motion is by laser doppler velocimetry. In this technique laser light is scattered from the population of particles in motion, and the frequency shift induced by the motion, due to the doppler effect, is measured by a suitable detector and signal processor. The velocity can then be deduced knowing the geometry of the scattering arrangement.

The design of a chamber or cell for electrophoretic measurements using laser doppler velocimetry to analyse the motion, entails the achievement of a suitably high field strength, to achieve a measurable velocity from what may be a particle of little charge coupled to an optical design which allows the entry, and exit, of enough laser power to produce measurable signals from what may be few particles of low scattering efficiency.

The achievement of high field strength is particularly necessary, though not limited, to the application of laser doppler electrophoresis in the study of particles in media by low dielectric constant, where a given charge results in a low velocity. An example, not exhaustive, of such a situation would be a suspension of carbon particles in dodecane where the dielectric constant is about 1/40 of an aqueous salt. The achievement of high field strength is well implemented by closely spaced electrodes. It is important that the field by spacially uniform so that a distribution of field and hence velocities in space does not result across the measurement zone.

These requirements lead to an idealised cell consisting of charged uniform, flat parallel plates. The laser beam must be at an angle to the co-normal of the plate axes and the detector direction should ideally be in the general direction of travel of the laser beam to maximise the light scattering by finite sized particles. Practical systems in the prior art using cells of this form have had to adopt very small angles to achieve large plate electrodes to avoid collision between the plate and the laser beam(s). This low angle leads to difficulties of design, because the small angle the laser beam can make with the direction of the applied field and hence the direction of motion, leads to low doppler frequency shifts and difficult measurement conditions.

It is an object of this invention to provide means whereby the above difficulties may be alleviated.

Accordingly this invention provides a microelectrophoresis cell for a laser doppler electrophoresis system wherein the coherent light path into the sample analysis zone of the cell passes through an optically transparent electrode which is arranged to apply the actuation charge across the sample.

Preferably both electrodes of the cell are optically transparent and lie across the paths for two separate beams of coherent light. In this instance it is advantageous to include reflecting surfaces for directing the two beams to a crossing point in the sample analysis zone. By using transparent electrodes it is possible to achieve high beam angles. The electrodes can be large in area by comparison to the beam size and electrode spacing but, because a comparatively large scattering angle can be used, detection of the scattering effect is greatly enhanced.

Instead of a dual beam system a single beam can be directed at an angle to the co-normal of the electrode plate axes whilst the unit will include transmission means for projecting a reference beam of coherent light into the output path for light beams emitted from the cell. This transmission means could comprise a fibre optic beam transmitter.

The complete cell system may incorporate the necessary detector for the emitted light beams aligned in a plane lying between the planes of the electrodes.

Fibre optics or other means for bringing a beam to a point at or near the transparent electrode may be utilised instead of rectilinear propagation of the laser beam. In this case the transparent electrode may act as a lens, partial-reflector or window to admit entry or accept exit of incident or scattered light to or from the sample analysis zone.

In the preferred arrangement the transparent electrode will comprise a discrete plate of indium tin oxide or an indium tin oxide coating applied to optical glass. Alternatively the electrode could comprise a film of metal applied to optical glass to a thickness sufficiently small to allow measurable light to pass therethrough. Fine wires may be bonded to the electrode layer or a surface coating of a conductive metallic film may be applied to the electrode layer, to which contact can be made by fixed wires or otherwise.

The invention may be performed in various ways and a preferred embodiment thereof will now be described with reference to the ac-

companying drawings, in which:—

Figure 1 is a diagrammatic illustration of a microelectrophoresis cell of this invention; and

Figure 2 is a vertical section on line II–II of Fig. 1.

The sample cell shown in the drawings defines a sample introduction and exhaust flow path 1 passing through a sample analysis zone defined between a pair of electrodes 2. Each electrode comprises a sheet of optical glass (forming a wall of a prism 3) carrying a polished film of indium tin oxide to which an electrically conductive wire has been connected. This connection is achieved by external pressure contact of the wire 4 to gold plating 5 applied to the top face of the prism 3. The gold coating wraps around the edge of the prism for a short distance under the indium tin oxide coating. The field created when a potential is applied between the electrodes 2, has a direction as indicated by the double-headed arrow 17. Laser beams 6,7 produced from a coherent light source are reflected by angled surfaces 8,9 or the prisms so that they pass through the transparent electrodes 2 and cross within the sample analysis zone 10 between the electrodes. The light scattering effect created by the particles is measured by a photomultiplier 11 after passing through an optical system 12 aligned on the axis of the flow path 1.

As a modification of the system illustrated, only one of the laser beams 6,7 is used but a reference beam of coherent light, suitably attenuated, is passed, such as from a unit 13, directly to the detector system 11,12, so that light with no doppler shift is mixed with scattered light. Alternatively, a reference beam could be passed by some other means than directly through the sample flow path 1, to the detector system 8,9 such as by a fibre optic member 14, from a unit 15. Furthermore the laser beam 6,7 may be brought to the electrode face 2 by such means as optical fibres (as indicated at 16). The electrode material 2 might then be used as a lens, reflector or window to admit entry or accept the exit of incident or scattered light.

The electrode layer 2 is ideally of tin oxide with a small doping of indium, which improves electrical conductivity. However, other electrically conductive materials having a high value of light transmissivity may be used, such as thin coatings of noble metals.

CLAIMS

1. A microelectrophoresis cell for a laser doppler electropohoresis system wherein the coherent light path into the sample analysis zone of the cell passes through an optically transparent electrode which is arranged to apply the actuation charge across the sample.

2. A cell according to claim 1, wherein both electrodes of the cell are optically transparent and lie across the paths for two separate beams of coherent light.

3. A cell according to claim 2, including reflecting surfaces for directing the two beams to a crossing point in the sample analysis zone.

4. A cell according to claim 1, including transmission means for projecting a reference beam of coherent light into the output path for light beams emitted from the cell.

5. A cell according to claim 4, wherein said transmission means comprises a fibre optic beam transmitter.

6. A cell according to any one of claims 1 to 5, including a detector for emitted light beams aligned in a plane lying between the planes of the electrodes.

7. A cell according to any one of claims 1 to 6, including fibre optics or other means for bringing a beam to a point at or near the transparent electrode.

8. A cell according to claim 7, wherein the electrode acts as a lens, partial-reflector or window to admit entry or accept exit or incident or scattered light to or from the sample analysis zone.

9. A cell according to anyone of claims 1 to 8, wherein the transparent electrode comprises a discrete plate of indium tin oxide or an indium tin oxide coating applied to optical glass.

10. A cell according to any one of claims 1 to 8, wherein the electrode comprises a film of metal aplied to optical glass to a thickness sufficiently small to allow measureable light to pass therethrough.

11. A cell according to claim 9 or claim 10, wherein fine wires are bonded to the electrode layer, or a surface coating of a conductive metallic film is applied to the electrode layer, to which contact is made by fixed wires or otherwise.

12. A microelectrophoresis cell substantially as herein described with reference to the accompanying drawings.

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